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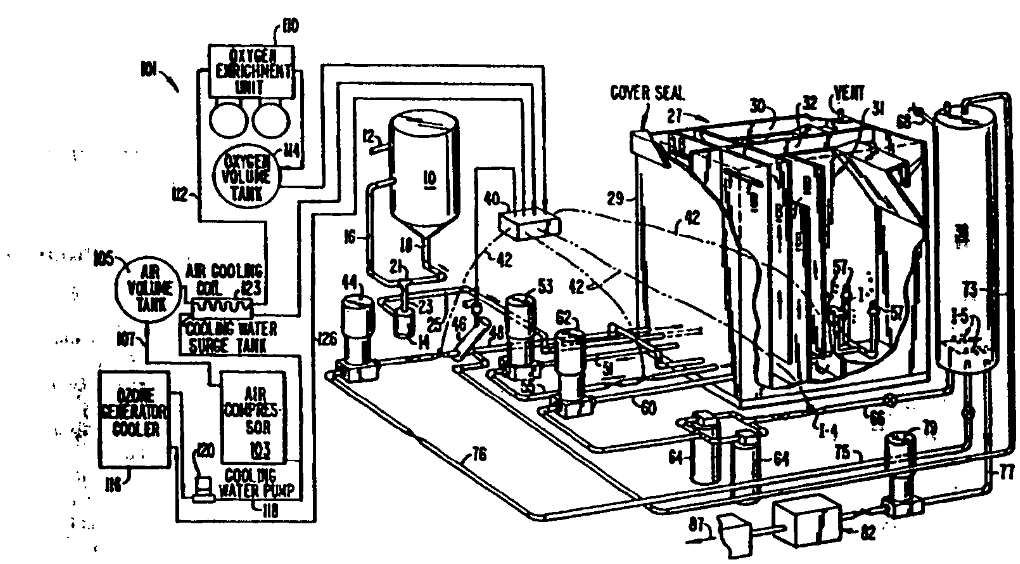

(57) Abstract

A process and system for purifying water containing solid, chemical, and/or bacterial wastes is described. Contaminated water is introduced (25) to a pre-charged chamber (30) defining a solid clarifier stage in which the water is bombarded with gaseous oxidant (I) to cause flocculation of the solid contaminants. The flocculated solids are removed, and the water is saturated with gaseous oxidant and passed into a fluid body (38) at ambient atmospheric pressure so as to cause the gaseous oxidant in the water to expand and thoroughly mix with the fluids, destroying bacterial and chemical contaminants. A portion of the resulting mix fluid is withdrawn (77), subjected to UV radiation (82), and degassed (85). The remainder, between 30 % and 37 % of the total volume of contaminated fluid introduced to the tower, is recirculated (75, 76) back to the solid clarifier stage (30) and processed again.

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APPARATUS FOR REMOVAL OF SOLID, CHEMICAL AND BACTERIAL WASTE FROM WATER

FIELD OF THE INVENTION

The present invention relates to a process and system for the removal of solid, chemical and/or bacterial wastes from water.

PRIORITY BASED ON EARLIER-FILED APPLICATIONS

This application claims priority from the following earlier-filed U.S. applications: Serial Number 07/893,812, filed June 4, 1992, and Serial Number 07/924,452, filed August 4, 1992. These applications are incorporated herein by reference for all purposes.

BACKGROUND OF THE INVENTION

Since time immemorial, it seems that there has been a conflict between the industrialization of the continent and its burgeoning population. Not until 1970, however, did this conflict become a matter of national conscience by virtue of the passage, by Congress, of the Environmental Quality Improvement Act, which, together with several Executive Orders, established the EPA and several other related organizations. Since that time, however, the high-minded goals of the EPA have become stark reality for millions of people whose rudimentary requirements for existence have become threatened by the by-products of an industrial age.

Fundamental to the needs of human beings, is their water supply. Irrespective of the source of that supply, be it melting snows, subterranean ponding and/or alluvial flow, or even by virtue of the desalinization of ocean waters, is an absolute indispensable necessity of life. In those areas where the water supply is essentially subterranean, it is highly susceptible to pollution through industrial, chemical, agricultural, and even human waste, which percolates from the surface through the soils to the supply. In more arid areas,

due to burgeoning populations, it is not realistic to believe that sufficient potable water supplies can be divined without reclamation, and it has become vital, indeed crucial, for means to be devised for the removal of pollutants, including such chemicals as DBCP, from the water supply in an efficient and timely manner, in order to meet the demands placed on this natural resource. The present invention addresses, and meets, this and similar quandaries faced by man, and presents a truly unique and practical solution.

On a different level, while still focusing on the environment, the invention finds great utility in the processing of industrial and municipal waste water. Due to its versatility and compactness, its use promises great efficiency and financial savings over present day state of the art systems.

While the present invention does not claim to be a pioneer in the use of oxidants, such as ozone, in the treatment of waste water, it does provide a unique process for removal of solid, chemical and bacterial wastes from such waters. Certainly prior to the closed loop system of Lee, et al. Patent No. 3,856,671, issued in 1974, scientists, recognizing the value of oxidants other than chlorine in water treatment, sought ways of effective use of the oxidation process in water treatment. One of the more erudite, but somewhat impractical, efforts is described in Stopka Patent No. 4,176,061, which extols the use of a very long, small diameter conduit as a mixer and clarifier, which is maintained, under pressure, to increase the exposure time between the fluid to be treated and ozone. The specification itself, however, provides a rather good chronology on the history of water purification.

Still other efforts to take advantage of the basic reaction between an oxidizer such as ozone, and the fluid to be treated may be found in such patents as Donnelly, et al. 4,053,399, Kirk 3,945,918, Herbrechtsmeier et al. 4,353,717, Turk 4,029,578 and Dananault 4,332,687. Upon review of these patents, however, it will be appreciated that none of these patents, either singly, or in any reasonable combination, suggests or disclose the present invention.

SUMMARY OF THE INVENTION

The present invention has several laudable objectives, all of which are accomplished by the process and apparatus of the present invention, among them are:

to make optimum use of the known reaction between ozone and dissolved and undissolved solids, chemicals, and bacterial wastes in water, in a multi-phase system and by means of a continuous process of reintroduction, mixing, and interaction, between fluid to be treated and an oxidizing mixture, remove such impurities in the treated water to provide an environmentally acceptable end product;

to provide a process for purification of water which can accommodate substantial quantities of treatable solution in a relatively small and compact space, and within a relatively short period of time;

to provide a two-stage, multi-phase system wherein solid matter is removed in an initial stage, and chemical and bacterial contaminants are removed in a second stage, and further providing means for recirculating portions of the treated water through the system until the desired level of purification is reached; and

to provide a two-stage system in which the initial stage can be by-passed for the treatment of contaminated solutions in which there is no solid matter to be removed.

All of these objectives, and others, are readily accomplished by the process of the present invention in which the waste water to be treated is initially sprayed into a chamber while being bombarded, and mixed, with ozone dissolved in an oxygen-rich carrier while under pressure, which expands in the clarifier and intermixes with the water to be treated in the form of small bubbles most preferably having an average diameter of between about one to seven microns.

The intimate mixing of ozone and solids in the treatment water results in flocculation of a portion of the waste, which then floats to the top of the tank where it may be removed. The waste water is then injected with additional oxidant prior to dispersing the waste water at a first pressure into a mixing tower, which is at a second, lower pressure

oxidant and waste water are thoroughly mixed before drawing off a first portion, approximately 30%, of the mix from the tower as finish water, and recirculating a second portion to a location upstream of the tower. The finish water may be processed further to remove bacteria, residual gases and microparticles, e.g., by exposing the finish water to ultraviolet light and/or passing the finish water through carbon filters.

The invention also contemplates apparatus for the accomplishment of the process previously described.

BRIEF DESCRIPTION OF THE DRAWINGS

Having thus described the environment in which the present invention has particular, although not exclusive, utility, a preferred embodiment of the present invention is illustrated in the drawings, wherein:

Fig. 1 is a schematic illustration of the two-stage multi-phase process of the present invention;

Fig. 2 is a simplified perspective of the apparatus capable of performing the process of the present invention; and

Fig. 3 is a schematic illustration of an alternative form of the process, wherein the first stage of the process relating to removal of solids from the treatment fluid is bypassed.

DESCRIPTION OF SPECIFIC EMBODIMENTS

With reference now to the drawings, and particularly Fig. 1, a preferred embodiment of the process of the present invention is illustrated in considerable detail, and in order to provide a complete understanding of the process, and its novel aspects, a quantity of polluted or contaminated aqueous fluid to be treated (hereinafter referred to as "waste water") will be followed through the process of purification.

Fig. 1 schematically illustrates a complete two-stage process of the present invention by which waste water may be treated to remove solid, chemical, and bacterial wastes with a high level of efficiency and control.

Since the process, and the associated apparatus involve considerable recirculation of waste water, the delineation between stage one of the process, which is intended to remove primarily solids and precipitants, and stage two, which is intended to remove primarily chemical and bacterial wastes, tends to be somewhat blurred. However, reference to Fig. 3 will assist in distinguishing the principal elements of the process of each stage, in that Fig. 3 is intended to illustrate primarily the second stage of the process.

Assuming that the system has been charged with water, which is the necessary to render the system operative, waste water is received in a surge tank 10 at inlet 12, and is drawn into the precharged systems by means of a pump 14 of known construction, the precise capacity of which will be determined by the specific application. The inlet side of the pump (also seen in Fig. 2) draws waste water from the tank through a high suction line 16, and a low suction line 18, both of which meet at a T connection 21 immediately prior to entering the pump at 23. It will be noted that the system is replete with valves, which may be of the check type, as well as manual or remotely controlled valves without departure from the invention. In order to simplify the explanation of the process and its associated system, each of the check valves will be designated by the letter C, and will be numbered only to the extent that it is essential to a full understanding of the process.

In accordance with one aspect of the invention, the waste water discharge from pump 23 is forced, under pressure, through line 25 into a solids removal unit 27, which comprises the principal treatment element of stage one of the process.

The physical makeup of the solid removal unit is best illustrated in Fig. 2, where it will be seen that a tank 29 is provided, which is divided into two substantially identical clarifier chambers 30 and 31, respectively, by means of wall 32. Each of the chambers contain vertically- and serially-disposed baffles, B, aligned in the direction of flow through the chamber. It will be appreciated that, by using a single tank, constructed in the fashion illustrated in Fig. 2, the apparatus of the present invention is both compact and

efficient in its use of space and plumbing. However, it is equally apparent that the clarifier chambers could be separated, or formed in a different fashion, without departure from the invention. It will be further appreciated that any number of such chambers may be used, or none at all (see the discussion with respect to Figure 3 below), depending on the nature of the waste water, without departing from the scope of the invention.

Reverting to Fig. 1, line 25 passes directly into the first chamber 30, where it is connected to waste water dispersal nozzles 34. While two such nozzles are illustrated, any number of nozzles may be employed.

As indicated at the beginning of this discussion, the system has been precharged, and in so doing, chambers 30 and 31 have been filled with primer water, which may enter the system at 36 from a suitable outside source, or alternatively, the initial charge may be received from the contact tower 38, through a part of the recirculation system which will be described hereinafter.

The process takes advantage of understood oxygenating principles, while avoiding the use of chlorine and other halogens which tend to be unstable, volatile, and otherwise difficult to handle. A powerful, yet controllable, oxidant is provided through an ozone generator 40 of common construction and materials. The generator generates large amounts of ozone, which it combines with a highly oxygenated carrier, to form a gaseous oxidant which is referred to herein as simply, "the oxidant". The oxidant is dispersed throughout the system by several lines, illustrated in Fig. 1 as dashed lines 42.

In order to optimize dispersal of the oxidant into the waste water flow, where it is entrained most preferably in the form of small bubbles, the invention contemplates the use of oxidant injectors, such as, for example, the Mazzei injector. Thus, distribution lines 42 connect directly to each oxidant injector I, located throughout the system, and which are indicated generally by the letter I, except that, to the extent that a particular injector, or series, or bank, of

injectors, is accorded a number in order to facilitate understanding of the process.

An initial charge of primer water feeds pump 44, which forces primer water into the first and second chambers, through injectors I-1. In keeping with the present invention, the primer water first receives an initial injection of oxidant, also through the injectors I-1, located in the tanks downstream of the pump 44. It is most preferable to saturate the fluid in line 48 with oxidant. To facilitate saturation, an air purge chamber 46 may be located downstream of the oxidant injection area, comprising a relief tank into which excess gases dissolved in the waste water may be relieved from the system, i.e., gases which have not become entrained in the fluid in the line 48.

Concentrating on the first stage clarifier chamber 31, a series of injectors I-2 are disposed in the tank or chamber in immediate proximity to the discharge nozzles 34 through which waste water is sprayed into the chamber 30. Thus, in accordance with the invention, waste water is discharged into the chamber, and into primer water which has a precharge of oxidant, and additional oxidant from the generator 40 is coincidentally injected into the spray of waste water emanating from the nozzles 34, bombarding this influent waste water with large amounts of oxidant. It is a novel feature of the process of the present invention, that, even though waste water and oxidant are injected into the chamber 30 under pressure, the chamber itself, is at a lower pressure relative to the injected water and oxidant. This enhances mixing of the oxidant with the stream of waste water flowing from the nozzles 34, and create small bubbles having an average diameter in of a range between 1 and 50 microns, preferably between 1 and 20 microns, and most preferably between 1 and 7 microns; thereby greatly increasing the surface contact between the waste water and the oxidant. Because of this greatly increased exposure, flocculation, i.e., clumping together of solids in the waste water into larger, capturable masses, is achieved; and the process, which would otherwise occur at a slow rate, instead occurs at a high rate, resulting in significant amounts of

solid wastes being carried to the top of the chamber or tank 30, where it is drawn off or otherwise removed by any suitable means, such as paddles.

The waste water from injectors 34, now entrained with oxidant, is passed over and under the baffles B in a tortuous path, resulting in enhanced intermixing, and commensurate increased flocculation and eventual removal of solid matter.

Since, however, it is a goal of the present invention to remove virtually all solid waste matter, the discharge from the first phase clarifier chamber 30 may be passed to a second such chamber. As illustrated in Figure 1, discharged waste water from chamber 30 is passed through line 51 to pump 53 into line 55, where, once again, the waste water is bombarded with oxidant, through injectors I and forced under pressure into the second clarifier chamber 31, which has been previously charged in the same manner as chamber 30, and into the tank through injectors 57. As was the case in chamber 30, oxidant injectors I-3 are disposed in immediate proximity to the nozzles 57, and the waste water again passes over and under the baffles B, resulting in the flocculation and ultimate removal masses of typically smaller particles of solid matter entrained in the waste water. However, it will be appreciated that such a second processing may not be necessary or, alternatively, that further processing in additional chambers may be required, depending on the exact nature of the waste water to be treated.

Generally, by the time the waste water is ready to exit the second phase clarifier chamber 31 virtually all of the larger solids in the waste water have been removed, and depending upon the make-up of the waste water to be treated, practically all of the macroscopic solids have been fully removed. Accordingly, waste water, which exits the chamber 31 through line 60 has been largely purged of solids, and is ready for entry into the second stage of the process.

The second stage of the process of the present invention, begins at pump 62, which draws waste water from the chamber or tank 31, and sends it to contact tower 38. In one embodiment of the invention, illustrated in Figures 1 and 2, the waste water is forced through a pair of filters 64, which,

as illustrated, are disposed in parallel, and which are intended to pick up any additional solids that may be entrained in the waste water. However, it will be appreciated by those skilled in the art that such filtration may not be required depending on the nature of the contamination. The filtered waste water is then forced, still under pressure, through line 66 to the contact, or mixing, tower 38. Prior to entering the contact tower, however, the waste water in line 66 may be bombarded again with oxidant by means of an injector I-4 disposed in line 66. Again, such additional injection may not be necessary depending on the nature of the contamination of the waste water. It will also be appreciated that the embodiment shown and just described is but one of several arrangements of filters and injectors which could be made without departing from the scope or principle of the invention.

The contact tower 38 is the principal interacting element of the second stage purification process, and, as illustrated in Fig. 2, is of a cylindrical shape, disposed on a vertical axis. The tower is charged with a fluid body which may be charge water (see above) or waste water.The purpose of the tower is to intimately mix the fluid discharge from stage one, and the oxidant entrained therein, and provide sufficient contact time to allow for thorough intermixing in a fluid body or column, and, therefore, its specific construction may assume any physical form which will accomplish the purpose.

As illustrated, the tower receives waste water from the filters 64, and which has been injected with oxidant at injectors I-4. This oxidant-entrained waste water is then sprayed into the fluid body through injectors I-5, which causes the mixture to be dispersed into the fluid body and waste water in small bubbles, having an average diameter in of a range between 1 and 50 microns, preferably between 1 and 20 microns, and most preferably between 1 and 7 microns; thereby effecting excellent surface contact between the oxidant and the waste water while in the tower. Since fluid body is at a lower pressure relative to the injected oxidant-entrained waste water, bubble formation is enhanced in the fluid column formed within the tower, and substantial and rapid intermixing of

waste water, and the expanding gaseous oxidant entrained therein is achieved as the mixture exits the injectors. With a very significant amount of the solids having previously been removed from the waste water, little additional flocculation takes place, and the oxidant, instead of being used up in the flocculation process, interacts with chemical and bacterial impurities in the waste water; thereby resulting in the breakdown and destruction of such impurities.

It is a feature of the present invention to insure cost effective purification of waste water by controlled recirculation of a predetermined portion of the waste water in the contact tower back to stage one of the system. By use of recirculation, the size of the ozone generator required, and the cost associated with ozone generation, is, likewise, controlled.

In accomplishing this objective, an upper recirculation line 73 draws lighter components of the waste water from the top of the contact tower 38, and together with heavier components of the waste water drawn from the bottom of the tank, is recirculated through lines 75 and 76 back to the inlet and exit sides of pump 44, respectively, where it is again recirculated through the entire system.

Further, in accordance with this feature of the invention, a relatively smaller portion of the waste water in the contact tower 38 is drawn off through line 77 by pump 79 as finish water. In accordance with one aspect of the invention, the finish water from pump 79 is forced under pressure through an array of ultraviolet lights in UV system 82, which irradiate any remaining bacterial impurities that may have survived the process to that point. The finish water may also be passed through valve C-1 into a bank of carbon filters 85, which degas and polish the product, after which it is discharged through line 87, and out of the system. However, it will appreciated that the post-processing of the finish water may be accomplished in many diverse ways, such as through the addition of chlorine or other bactericides, depending on the nature of the contaminants and the final destination of the finish water. It will also be appreciate that no post-processing may be

required, for example, where the finish water is to discharged to the ocean.

By way of example, tests on the system, based upon a given waste water analysis, have demonstrated that if approximately 70% of the waste water from the contact tower is recirculated, while 30% is drawn off for treatment by UV and carbon filters, all of the objectives of the invention are accomplished. Typically, recirculation of 70% of the volume would be a maximum, whereas 30% would be a minimum. In this example, if the system inputs 10 gallons per minute (GPM) of waste water from the bank 10, and discharges 10 GPM through line 87, by virtue of the precharged system, depending on the composition of the waste water approximately 25 gallons per minute may be recirculated, with a resultant purification of the waste water to virtually any level required by the user.

With reference to Fig. 3, it has been found that, where the waste water to be treated, is substantially, if not virtually free of solids, the time and power requirements for passing the waste water through the first stage through valve C-2, the process is rendered significantly faster, without sacrifice of its efficiency.

With reference to Fig. 3, under circumstances where it is determined that solids in the waste water to be treated are insignificant, the apparatus provides means for bypassing the stage one clarifier system. Specifically, bypass line 93 interconnects line 25 and line 60, and by manipulation of control valves C-3 and C-4, stage one of the system is bypassed. The process of stage two is the same as that previously described.

In practical application, an initial controlled sample of the waste water to be treated is first analyzed. A controlled volume is then run through a pilot unit, which is basically a downsized embodiment of the invention; and, through timing and discharge analysis, the pressure, volume and time of processing, as well as the ratio of recirculation to discharge from the contact tower can be determined. The volume of ozone required to obtain the desired end product can also be determined using techniques well-known in the art.

The invention as just described is capable of taking advantage of certain performance enhancing modifications to the ozone generator 40. With reference to Fig. 1, for example, a molecular sieve air separator, 101 is provided, which force feeds the ozone generator 40, with a supply of greatly enriched oxygen, under pressure, much in the same way as a supercharger is used to supply a compressed air supply to an engine.

The molecular sieve air separator 101, in accordance with this aspect of the invention, receives a supply of gaseous fluid, which is compressed by means of air compressor 103, and initially stored in a receiving tank, or plenum 105, which connects to the air compressor through feed line 107.

Compressed air from the plenum 105 is fed to a pressure swing separation unit 110, through line 112, where the nitrogen and oxygen molecules in the air are separated out. In practice, the separator unit 110 separates nitrogen and water vapor from intake air, and a dry gas containing up to 90% oxygen. The dry oxygen gas is then stored in an accumulator, 114, and from there, fed to the ozone generator 40.

It has been found that the performance of the sieve generator 101, as well as that of the ozone generator 40 is optimized by cooling of the compressed air, as well as the ozone generator input to a controlled temperature, in the range of 65° to 70°F.

Accordingly, a closed cooling system is provided, which includes a water cooler 116, of any well known type. The cooler connects to the ozone generator 40, by means on cooler input line 118. A circulation pump 120 assures constant movement of the coolant.

Line 118 is passed through a coolant surge tank 123 on its way to the ozone generator 40 to provide a lowered temperature to the air accumulated in tank 105 as it passes to unit 110. Since the compression process inevitably results in some temperature increase, by passing intake line 112 through the surge tank 123, the compressed air will be introduced into the separator at a more ideal temperature and density. Similarly, the coolant is introduced at the intake side of the ozone generator 40 and, thence, recirculated through return

line 126, resulting in a cooling at the ozone generator, with a commensurate increase in performance. Indeed, the size, cost and power requirements of the ozone generator may be reduced for a given application, thereby providing an additional cost saving.

In order to permit the solids removal unit 27 to make maximum advantage of the enriched ozone environment, there is provided, in accordance with this aspect of the invention, a cap seal 130 over the top of the solids removal unit. When the cap seal 130 is in place, and an air tight seal formed, a small pressure build up is experienced in the tank 29. It has been determined that a tank pressure of as little as ½ lb. will prevent the escape of noxious gases to the atmosphere, and the volume of entrained excess oxygen in the effluent is greater, rendering the ultraviolet exposure at the UV system 82, much more efficient.

Although the foregoing invention has been described in some detail by way of illustration and example, for purposes of clarity of understanding, it will be obvious that certain changes and modifications may be practiced within the scope of the appended claims.

WHAT IS CLAIMED:

1. A process for removing wastes from waste water, comprising the steps of:

(a) injecting a gaseous oxidant into said waste water, said waste water at a first pressure;

(b) introducing said waste water into a fluid body to form a mix fluid, said fluid body being at a second, lower pressure effective to cause said gaseous oxidant to expand and intermix with said waste water and thereby break down at least a portion of said waste;

(c) drawing-off a first portion of said mix fluid as finish water; and

(d) recirculating a second of said mix fluid to repeat steps (a)-(c).

2. The process of claim 1, wherein said gaseous oxidant expansion comprises small bubbles of oxidant.

3. The process of claim 2, wherein said gaseous oxidant expansion comprises bubbles having an average diameter of between about 1 and 50 microns.

4. The process of claim 3, wherein said small bubbles of oxidant have an average diameter of between about 1 and 20 microns.

5. The process of claim 4, wherein said small bubbles of oxidant have an average diameter of between about 1 and 7 microns.

6. The process of claim 1, wherein said waste water is filtered prior to introducing said waste water to said fluid body.

7. The process of claim 1, further including the step of degassing said finish water.

8. The process of claim 7, wherein said degassing is performed by passing said finish water through carbon filters.

9. The process of claim 1, wherein said finish water is treated to remove bacteria.

10. The process of claim 9, wherein said treatment comprises irradiating said finish water with ultraviolet light.

11. The process of claim 9, wherein said treatment comprises adding a bactericide to said finish water.

12. The process of claim 1, wherein said second portion comprises between about 30% and 70% of the total volume of said waste water introduced to said fluid body.

13. A process for removing waste from waste water comprising the steps of:

(a) introducing said waste water into a chamber by injecting said waste water into a portion of said chamber in a spray pattern;

(b) bombarding said spray with a gaseous oxidant;

(c) mixing said gaseous oxidant and said waste water so as to effect maximum contact therebetween to thereby cause flocculation of a portion of said waste;

(d) removing said flocculated waste;

14. The process of claim 13, wherein said mixing comprises dispersing said oxidant in the form of small bubbles.

15. The process of claim 14, wherein said bubbles have an average diameter of between about 1 and 50 microns.

16. The process of claim 15, wherein said bubbles have an average diameter of between about 1 and 20 microns.

17. The process of claim 16, wherein said bubbles have an average diameter of between about 1 and 7 microns.

18. A process for removing waste from waste water comprising the steps of:

(a) introducing said waste water into a chamber by injecting said waste water into a portion of said chamber in a spray pattern;

(b) bombarding said spray with a gaseous oxidant;

(c) mixing said gaseous oxidant and said contaminated fluid so as to effect maximum contact therebetween to thereby cause flocculation of a portion of said waste in said waste water;

(d) removing said flocculated waste from said chamber;

(e) filtering said waste water and injecting further gaseous oxidant to said waste water;

(f) introducing said filtered waste water at a first pressure into a fluid body to form a mix fluid, said fluid body at a second, lower pressure so that said introduction causes said gaseous oxidant to expand and thoroughly intermix with said waste water whereby a portion of said waste is broken down and destroyed;

(g) drawing off a first portion of said mix fluid as finish water; and

(h) recirculating a second portion of said mix fluid thereof to repeat steps (e)-(h).

19. A system for removal of waste from waste water, comprising:

(a) means defining a tank for initial removal waste matter from said waste water, said tank further including means for injecting a spray of said waste water therein;

(b) oxidant generator means;

(c) oxidant injector means in said tank located in close proximity to said spray means to thereby permit bombardment of said spray with gaseous oxidant to thereby cause flocculation of a portion of waste in said waste water;

(d) means in said tank for removing flocculated waste therefrom;

(e) means defining a mixing tower, said tower connected to said tank by a fluid discharge line, said discharge line including filter means for removing particulate matter from said contaminated fluid, and oxidant injector means for injecting additional gaseous oxidant into said waste water;

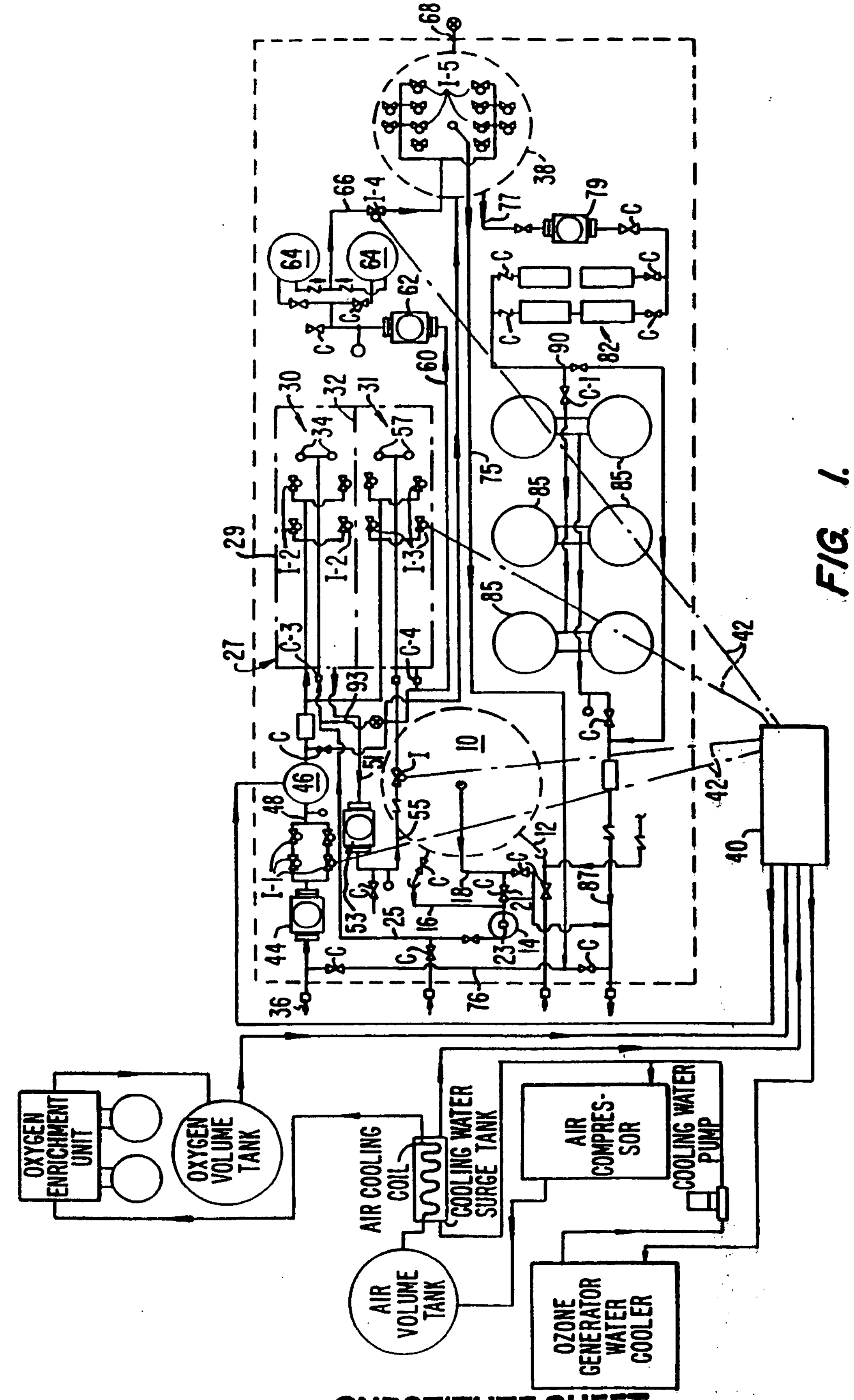
(f) means for moving said waste water in said discharge line from said tank to said mixing tower at a first pressure;

(g) said mixing tower holding a fluid body at a second, lower pressure so that upon introduction of said waste water a mix fluid is formed and said gaseous oxidant entrained in said waste water expands to form small bubbles which breakdown and destroy a portion of said waste;

(h) means for removal of a first portion of said mix fluid from said tower as finish water; and

(i) means for recirculating a second portion of said mix fluid to a location upstream of said tower, said recirculating means further containing oxidant injector means for introducing gaseous oxidant to said second portion.

20. The processes of claims 1, 13, 18, or the system of 19, wherein said gaseous oxidant comprises a mixture of ozone and oxygen.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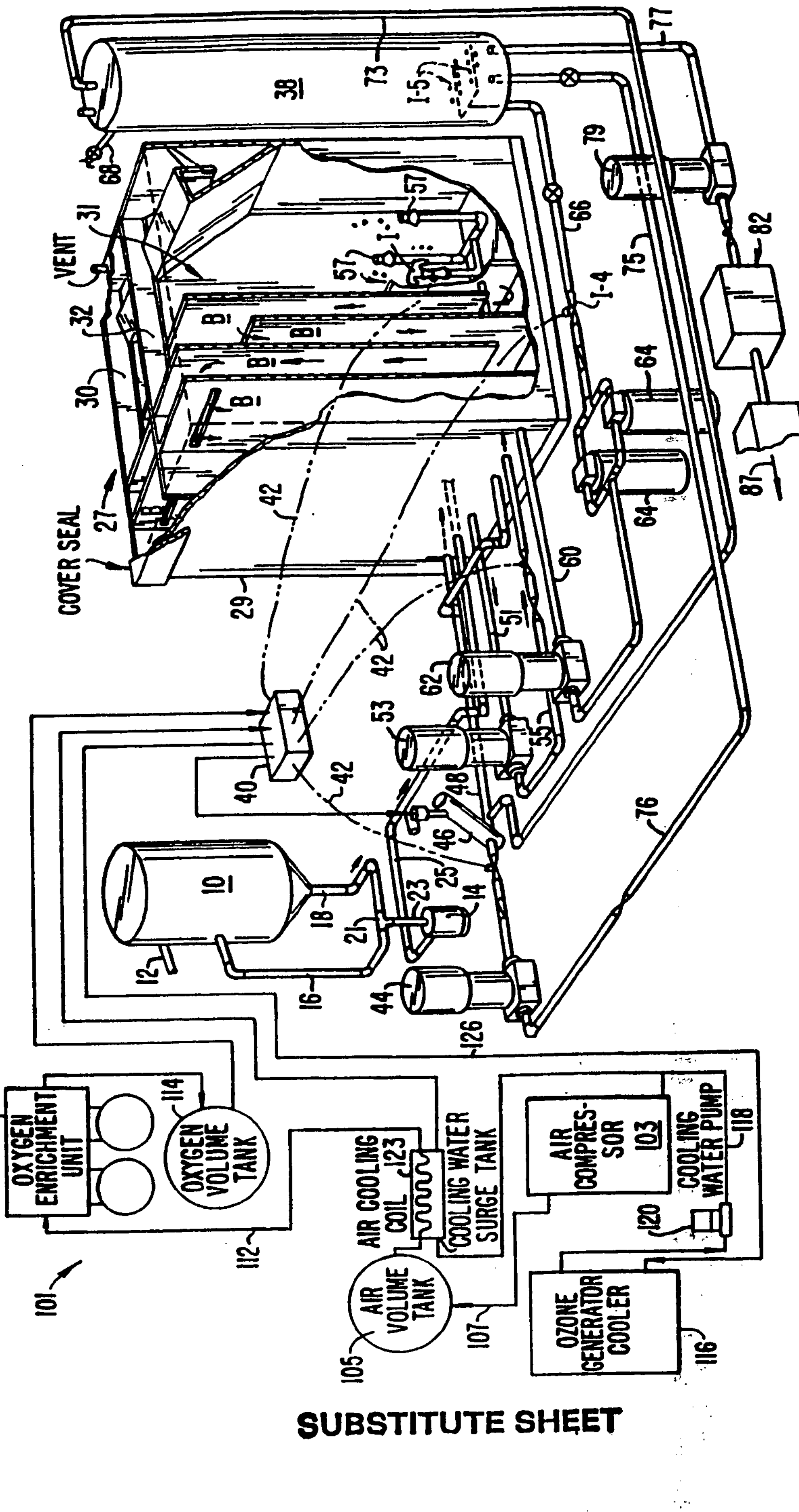
OXYGEN VOLUME TANK
AIR COOLING COIL
COOLING WATER SURGE TANK
AIR COMPRES-SOR
COOLING WATER PUMP
AIR VOLUME TANK
OZONE GENERATOR WATER COOLER

FIG. 1.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OXYGEN VOLUME TANK
AIR COOLING COIL 123
COOLING WATER SURGE TANK
AIR COMPRESSOR 103
COOLING WATER PUMP
AIR VOLUME TANK
OZONE GENERATOR COOLER
COVER SEAL
VENT

FIG. 2.

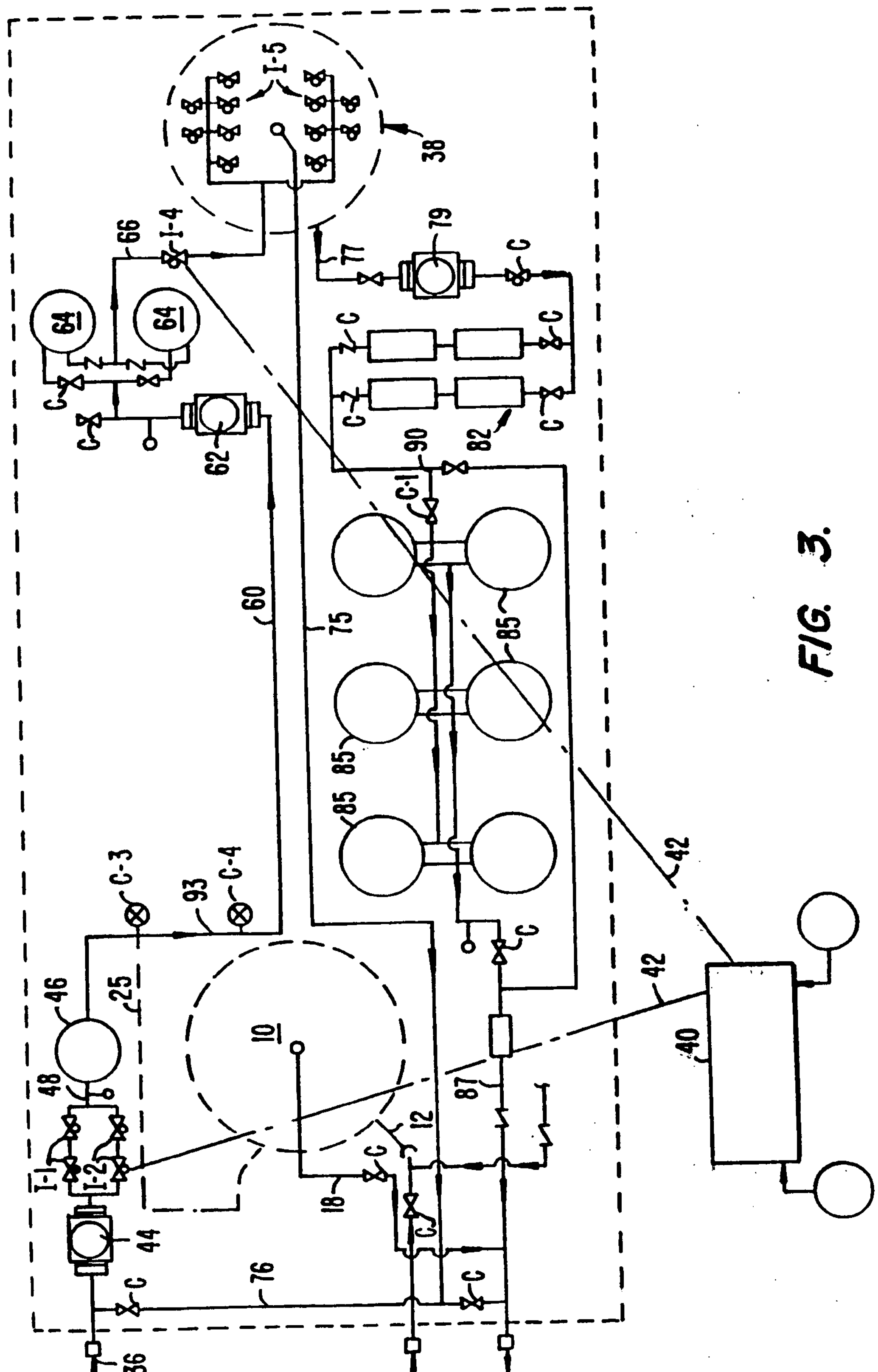

FIG. 3.

SUBSTITUTE SHEET

INTERNATIONAL SEARCH REPORT

PCT/US93/00465

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :C02F 1/32,1/78
US CL :210/192,712
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 210/195.1,205,220,703,706,718,721,738,748,750,752,758,760,765

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US,A, 3,772,188 (EDWARDS) 13 NOVEMBER 1973 See entire document	1,2,7,9-11,13,14 3-6,8,12,15-20
A	US,A, 4,412,924 (FEATHER) 01 NOVEMBER 1983 See entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 JUNE 1993	14 JUN 1993
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. NOT APPLICABLE	Authorized officer fv THOMAS G. WYSE Nguyen Ngoc-Ho Telephone No. (703) 308-3841

Form PCT/ISA/210 (second sheet)(July 1992)*